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Dielectronic Recombination of Low-Energy Isomers: Towards Storage Ring Studies of the 'Nuclear Clock' Isotope Thorium-229

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Long-lived atomic or nuclear states play an important role in astrophysics, for precision spectroscopy, for the study of fundamental symmetries, for energy storage or —based on their small natural widths—for applications as clocks. Within the scope of low-energy isomers 229(m)Th is truly outstanding in many aspects. It is presumed that 229 Th posses an isomeric state with excitation energy as low as 7.6 eV ([1], other values in the literature range from 0 – 15 eV [2]). It is thus the only isomer in the optical or near-optical range, i.e., suitable for laser experiments. Based on these features, a long list of ground-braking applications and physics cases is proposed (cf. [1, 2, 3] and Refs. therein). It is noted, that despite all efforts no direct evidence of the isomeric state has been published, yet [2].
Our approach for studying metastable states exploits the resonant electron-ion collision process of dielectronic recombination (DR) as a precision spectroscopic tool [4]. Experiments are performed with phase-space cooled few-electron ions at heavy-ion storage rings. For nuclear isomeric states, DR spectra show distinct resonance features that allow for a clear assignment without ambiguity. These 'fingerprints' arise due mainly to different hyperfine effects and nuclear volume shifts of ground and isomeric state.
As is outlined in the Technical Design Report of the "Storage Ring at HIE-ISOLDE" proposal [5], the application of the DR technique to investigations of long-lived nuclear states is considered a valuable asset to the physics program at the new nstallations. In my talk I will introduce and exemplify the technique with cases from atomic metastable states. In the main part, I will discuss a series of recent pioneering experiments carried out at the ESR ring in Darmstadt that leveraged the DR approach for the study of nuclear isomers. Successful experiments were performed with Li-like 234mPa88+ and 235mU89+. Here, 235mU is a particularly interesting candidate with a nuclear excitation energy of 76.8 eV [6] only, that is, the lowest evidenced isomeric transition, yet. It is worth emphasizing that in contrast to Schottky techniques the DR approach is also possible for such very low excitation energies. These initial results are very promising with respect to future extensions of this method and show ways how to implement the technique at the TSR at HIE-ISOLDE.

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Author: Dr BRANDAU, Carsten (ExtreMe Matter Institute EMMI and Research Division, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany)

Presenter: Dr BRANDAU, Carsten (ExtreMe Matter Institute EMMI and Research Division, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany)